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A COMPARISON OF THE EXTERNAL AND MIDDLE EAR OF MAN AND THE CAT.

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Preface.

In the present paper both the macroscopic and microscopic structure of the cat's external and middle ear will be discussed.

The gross anatomy of the cat's ear has already been described a number of times. There are, however, a few points in this comparison which I consider new. These will be specified when the parts are described.

I have found no description of the microscopic structure of the cat's ear. All statements here made concerning it are based on my own investigation.

My thanks are due to Professors B. G. Wilder and S. H. Gage for many valuable suggestions and much helpful criticism.

General Comparison.

It is a well-known fact that the cat's organ of hearing is far more sensitive than man's. Though this superiority may be largely due to the structure of the internal ear, it is fair to suppose that the external and middle ear also play their part in effecting it.

At the first glance this supposition would seem to be warranted. The trumpet-shaped pinna of the cat's ear is certainly a better con-

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ductor of sound than is the nearly flat pinna of man's ear. Its comparatively larger size also seems to be an advantage. If we may follow the teaching of Darwin, it would seem that in the course of evolution man had lost the admirably formed pinna which his ancestors undoubtedly possessed, and that it had become flattened by folding at the helix and antihelix, the point being thus turned in toward the concha. What Darwin considers the remnant of this point is still present in many human ears.

The comparatively larger size of the membrana tympani of the cat's ear, as well as its thinness, probably has some significance. The longer manubrium of the malleus and the slenderness of all the ossicles are also to be noticed.

The two-chambered tympanum of the cat's ear doubtless possesses some advantage over the one-chambered tympanum of man's. The precise effect the second chamber has, may not be clearly understood, but the fact of the presence of the tympanic bulla in all felidæ and in many other animals having an acute sense of hearing cannot be overlooked.

The manner in which the chorda tympani nerve of the cat crosses the tympanum is quite remarkable. The presence of a separate support to raise the nerve clear of the membrana tympani seems positive proof that it is to the cat's advantage to have the nerve thus raised.

The External Ear.

The pinna of the cat's ear, though similar in minute structure to that of man's, presents marked differences from it in form. It is in the shape of a funnel whose top has been cut off obliquely, thus giving it a pointed extremity at one side. Though man's pinna is not pointed, there is a small projection of the cartilage found in many human ears on the caudal edge and near the dorsal part of the helix, which Darwin considers a remnant of the point of the ear. (Descent of Man, vol. I, p, 21.) The concave surface of the cat's pinna is turned latero-cephalad. On the lateral border a pocket is formed as if by the splitting of the cartilage. It is lined with skin and is $1\frac{1}{2}$ to 2 centimeters in length and about 5 millimeters in depth. Just mesad of this pocket is a prominence which is probably homologous with the tragus of the human pinna. Just cephalad of this prominence and separated from it by a notch is a double prominence which may be homologous with the antitragus of man's ear. The dorsal half of this double prominence is covered with stiff hairs. There is no lobe on the cat's pinna, nor are there any folds corre-

sponding to the helix and antihelix of man's pinna. Farther mesad in the concha there are ridges and windings which are difficult of description and which do not appear to have homologues in the human pinna. The most prominent ridge extends cephalo-caudad and terminates at the caudal end in a large rounded prominence. Mesad of this and separated from it by a deep groove is a smaller ridge running parallel to it.

The skin covering the pinna is thick and tough and, except on a part of the concave surface, is covered with hair. On the mesal side of the concave surface there are some long hairs which reach nearly across the pinna. On the convex surface there is a tuft of hair projecting beyond the tip of the ear. Man's pinna has only a few delicate hairs upon it. In both man and cat the skin is connected to the frame-work by areolar tissue, the fibers of which run in all directions. The frame-work is a plate of elastic cartilage. (Fig. 1.)

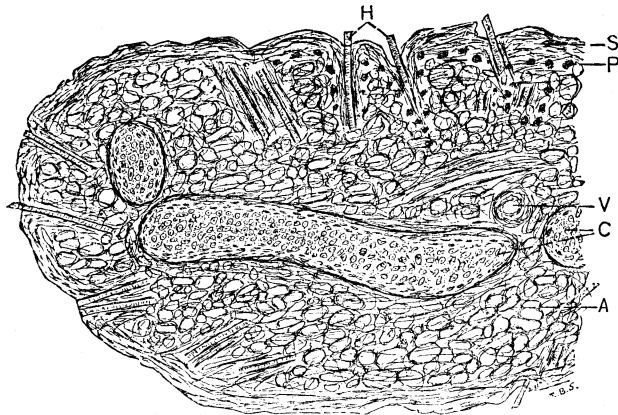


Fig. 1.—Transsection of the pinna of a cat. Cartilage cells drawn with a high power.

- | | |
|-----------------------------|------------|
| C—Cartilaginous frame-work. | P—Pigment. |
| A—Areolar tissue. | S—Skin. |
| V—Blood-vessel. | H—Hairs. |

The external auditory meatus of the cat is 2 to $2\frac{1}{2}$ centimeters in length and extends mesad to the membrana tympani. It is lined throughout with delicate skin. Its frame-work is cartilaginous nearly its whole length, two tubes of cartilage being joined end to end to form the single tube. The dorsal side of the osseous portion of the frame-work is very short, the ventral side being somewhat longer

because of the inclination of the membrana tympani. In man the dorsal side of the frame-work is entirely osseous. The ventral side is partly osseous and partly cartilaginous. The meatus of the cat's ear, unlike that of man's, extends into the tympanum for a short distance, thus giving the membrana tympani a position nearly in the middle of the tympanum. The surface of the meatus is uneven because of a number of small prominences upon it.

The structure of the meatus is similar to that of the pinna. There is a frame-work which is partly cartilaginous and a lining of thin skin which is partly covered with hairs. There is little areolar tissue, the space between skin and frame-work being filled with ceruminous glands and fat-cells. The same structures are found in the human meatus (Fig. 2).

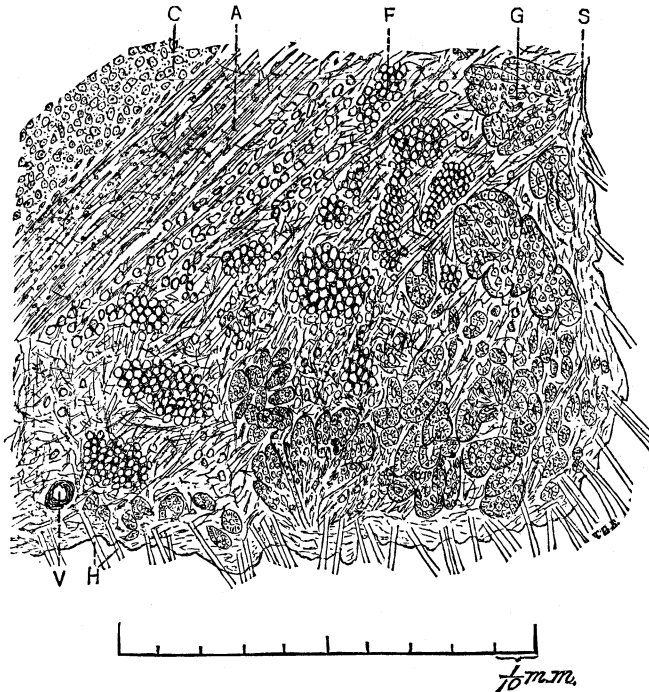


Fig. 2.—Transection of one of the prominences of the external meatus.

- | | |
|-----------------------------|-----------------|
| C—Cartilaginous frame-work. | S—Skin. |
| A—Connective tissue. | V—Blood-vessel. |
| F—Fat-cells. | H—Hairs. |
| G—Ceruminous glands. | |

The Membrana Tympani.

The membrana tympani of the cat is attached to a bony ring at the mesal end of the external auditory meatus. It is nearly in the middle of the tympanum, since the meatus extends into the tympanum somewhat. The membrana is more elliptical than in man, and its long axis extends cephalo-meso-ventrad. It is comparatively larger and is more nearly completely traversed by the manubrium of the malleus. It is convex on the mesal side and concave on the lateral, being held in that position by the manubrium of the malleus.

In minute structure the membrana tympani is about the same as in man, but it is thinner and more nearly transparent. Its delicacy of structure probably adds to its sensitiveness. As in man, there is a dermal layer, a fibrous layer, and a mucous layer. The dermal layer is a continuation of the skin of the meatus and is very thin. The fibrous layer is composed of radial fibers on the lateral side and circular fibers on the mesal side. The circular fibers are especially numerous at the periphery. The radial layer is closely connected with the dermal layer, and the circular layer is closely connected to the mucous layer. The mucous layer is covered with nearly spherical, ciliated, epithelial cells (Fig. 3, B.). Brücke states that the epithelial cells of the human membrana tympani are at times ciliated like those through the rest of the tympanic chamber. Hunt says: "The Eustachian tube is an involution of the pharyngeal mucous membrane; the meatus is an involution of the integument; the drum is formed by the Eustachian tube overlapping the extremity of the meatus." The manubrium of the malleus is between the mucosa and the fibrous layer. In the cat the blood-vessels of the membrana tympani form a series of loops from the periphery and also from the manubrium of the malleus, while in man there is a vascular net-work over the whole membrana.

The Tympanum.

The tympanum of the cat varies from that of man in having two chambers, the lateral chamber or tympanum proper, and the mesal chamber, which is larger and takes up the greater part of the large tympanic bulla. These two chambers are present in all felidæ. The tympanic bulla is present in many other animals, but I think there is no animal in which the partition between the two chambers is so nearly complete as in the felidæ. In the cat the partition between the chambers is a thin, long septum, which is incomplete at the

dorsal side just ventrad of the fenestra rotunda, leaving a means of communication between the chambers. A partial and incomplete

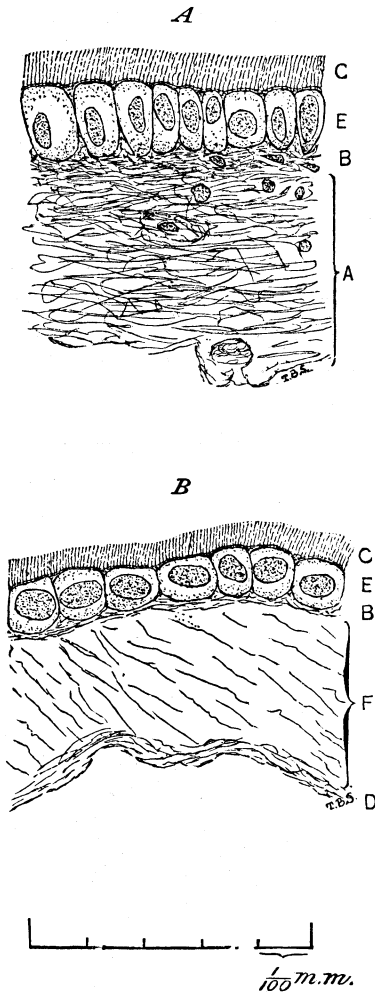


Fig. 3.—A—Lining membrane of the tympanum proper of the cat.

B—Transection of the membrana tympani of the cat. This was so sectioned that it does not show two fibrous layers.

C—Cilia.

E—Epithelial cells.

B—Basement membrane.

A—Connective tissue.

F—Fibrous layer.

D—Dermal layer.

partition is found in the dog's tympanum, running in a plane corresponding to that occupied by the septum in the cat's ear.

The tympanum proper of the cat is bounded nearly the same as in man, and all its walls are covered with a lining membrane. The internal ear is farther dorsad than in man, though this appearance is caused by the relatively larger membrana tympani extending ventrad. The septum between the chambers forms a large part of the mesal boundary. The tympanum, as in man, opens cephalad into the Eustachian tube. The mastoid cells are not so much reticulated as in man. In the orang the reticulations are very noticeable. They are also seen to some extent in the baboon. The tympanum proper contains the ossicles and other structures found in man's tympanum.

The mesal chamber of the cat's tympanum is empty, but it is lined throughout with a thin mucous membrane.

The lining membrane of the cat's tympanum has the same structure

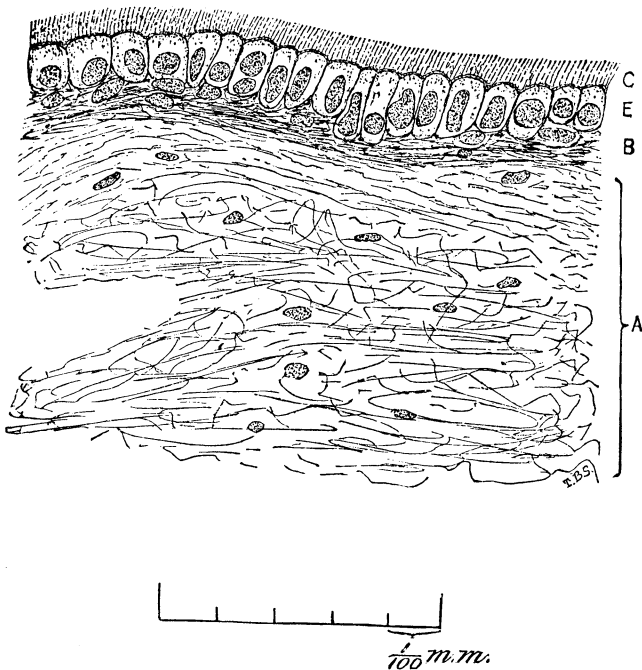


Fig. 4.—Membrane on the bony septum in the mesal chamber of the tympanum of the cat.

C—Cilia.

B—Basement membrane.

E—Epithelial cells.

A—Connective tissue.

as that of man's. It is thin, pale, and slightly vascular and is covered with a layer of ciliated epithelial cells. These cells vary in size in different parts of the chambers. The cilia also vary in length. The largest cells and longest cilia are found in the tympanum proper, both cells and cilia being shorter on the membrana tympani (Fig. 3). In the mesal chamber the epithelial cells on the membrane covering the bony septum are largest (Fig. 4). Those on the dorsal side are nearly as large, being only slightly shorter. They are much larger than those on the ventral side. The membrane, as a whole, is also much thicker, that on the ventral side being remarkable for its extreme thinness (Fig. 5).

As in man, there are three ossicles forming a chain across the tympanum. The head of the malleus and most of the incus are in a fossa in the dorsal part of the tympanum.

The manubrium of the malleus is fastened to the membrana tympani, extending between the mucosa and the fibrous layer. It is longer and more slender than in man. Perhaps its length contributes to its usefulness by conveying slighter vibrations of the membrana tympani than it otherwise would, the ossicle being more easily moved by the long lever. At the junction of the manubrium and neck is the processus brevis, a small process lying in contact with the membrana tympani. On the mesal side there is also a small cylindrical process, to which the tendon of the tensor tympani muscle is attached. This process is wanting on man's malleus. The neck and head of the cat's malleus, extending caudad, form an angle to the manubrium. The processus gracilis is long and flat and arises from the lateral aspect of the neck. The processus gracilis of the malleus of man is long and slender. The head of the cat's malleus is nearly spherical, and articulates by means of a diarthrodial joint with the head of the incus. The processus gracilis is held firmly by means of ligamentous fibers. There is also a suspensory ligament attached to the head, as in man. The tensor tympani muscle is attached to the small process on the mesal side of the neck by means of a short tendon. The muscle is nearly spherical and has its origin in a concavity slightly cephalad of the fenestra ovalis. In man the muscle is long and lies in a canal extending dorsad of the Eustachian tube and parallel to it.

The incus is of nearly the same shape as in man, resembling a molar tooth with two divergent fangs. The head articulates with the head of the malleus; the long process articulates with the head of the stapes by means of the lenticular process and a diarthrodial

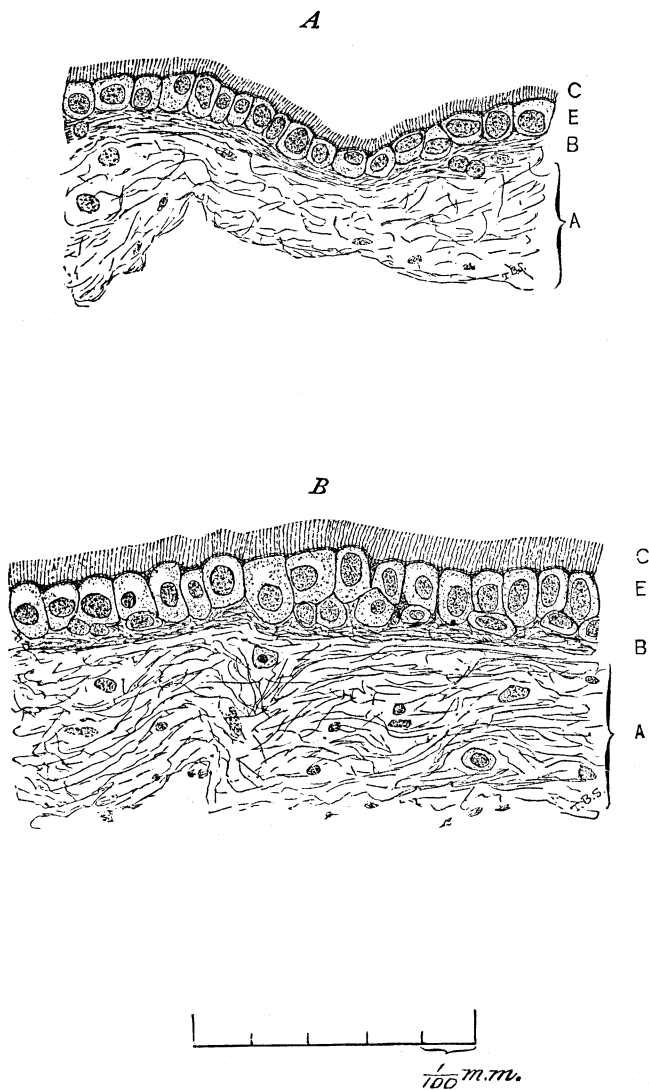


Fig. 5.—A—Membrane from ventral side of the mesal chamber of the tympanum of the cat.

B—Membrane on dorsal side of the mesal chamber of the tympanum of the cat.

C—Cilia.

B—Basement membrane.

E—Epthelial cells.

A—Connective tissue.

joint, and the short process is held by a ligament at the caudal part of the fossa, which is occupied by it and the heads of the incus and malleus. Straus-Durckheim describes the lenticular process as a separate bone. I think it is separate only in early life, as in man. "In early life the lenticular process is a separate ossicle." (Allen's Human Anatomy.)

The stapes of the cat is slight and fragile. As in man, it consists of a head, neck, two crura, and a base. The crura do not spread as widely as they do in man, joining the neck at a sharper angle. They are comparatively longer than in man and are very slender. The base is formed by a slight, elliptical ring of bone and a very thin plate of bone extending across the ring. The base is attached to the edge of the fenestra ovalis by ligamentous fibers, as in man. In this way the fenestra is completely closed. The tendon of the stapedius muscle is inserted upon a bony process on the caudal part of the neck of the stapes. The muscle is very small, and originates in a depression which is separated by a bony septum from the fossa occupied by the incus.

The chorda tympani nerve, as in man, extends across the tympanum, running dorso-cephalad. It crosses the malleus nearer the manubrium than in man, being entirely ventrad of the stapes and

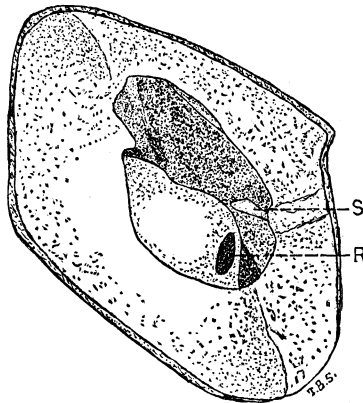


Fig. 6.—The left tympanum of the dried skull of a leopard. The bulla was broken into on the ventral side. Twice the natural size.

R—Fenestra rotunda. S—Support of chorda tympani nerve.

incus. This relation to these bones is in part due to the fact that the process of the incus does not extend far into the tympanum. The position and relations of the chorda also differ from those in man, in that the nerve is raised clear of the membrana tympani until it reaches the manubrium of the malleus. This is effected by means of a small support, which in early life is cartilaginous, but later becomes calcified. This support is 2 to 3 millimeters in length, about a millimeter in thickness at the base, and tapers gradually from base to point. It is joined by ligamentous fibers to the tympanic ring and extends into the tympanum cephalo-mesad (Figs. 6 and 7).

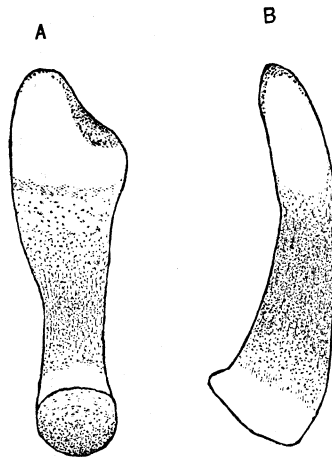


Fig. 7.—The support of the right chorda tympana nerve of the leopard.

A—Dorsal aspect.

B—Cephalic aspect.

Magnified about 15 diameters.

The nerve enters the tympanum at the base of the support and runs along its lateral side to its free end, whence it stretches across to the manubrium of the malleus. This support, like the ossicles of the tympanum, is infolded by the lining membrane of the tympanum (Fig. 8). The membrane, however, does not adhere to the whole length of the support, but spreads out at the base somewhat in the manner of the canvas of a tent upon its pole. The fold of membrane extends beyond the end of the support and envelops the nerve until it reaches the manubrium. There is no fold of mem-

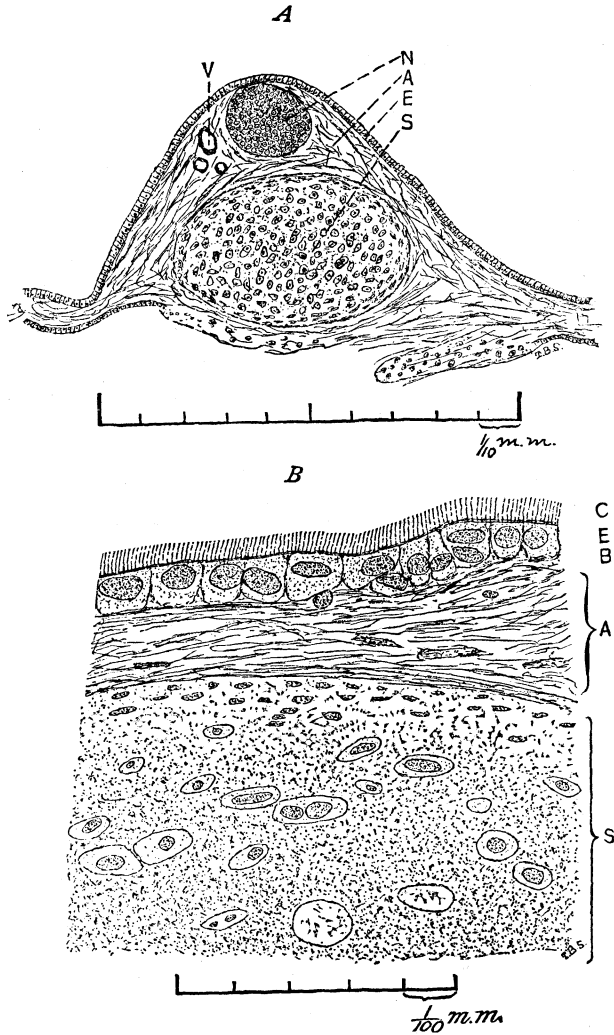


Fig. 8.—A—Transsection of the chorda tympani and its support. The details of the nerve and cartilage were filled in with a high power.

B—The support of the chorda tympani, and the infolding membrane.

N—Chorda tympani.

V—Blood-vessel.

A—Connective tissue.

C—Cilia.

E—Epithelial cells.

B—Basement membrane.

S—Support of chorda tympani.

brane between the nerve and the membrana tympani, there being a clear space between them (Figs. 9 and 10).

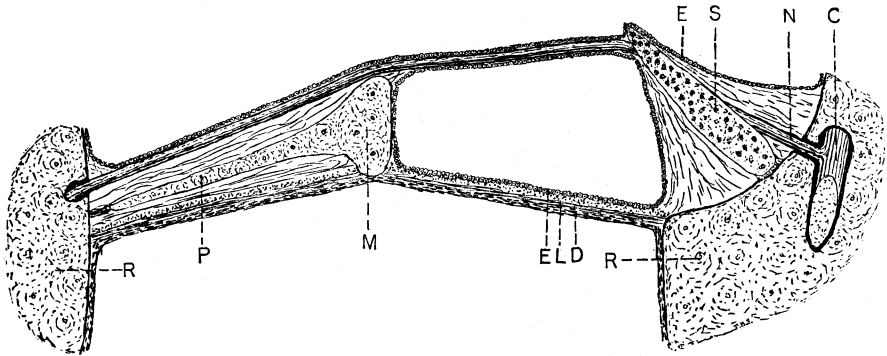


Fig. 9.—Diagram of a section of the membrana tympani of the cat, to show the relations of the chorda tympani and its support.

- | | |
|---------------------------|-------------------------|
| C—Seventh nerve. | L—Fibrous layer. |
| N—Chorda tympani. | D—Dermal layer. |
| S—Chorda tympani support. | M—Manubrium of malleus. |
| R—Tympanic ring. | P—Processus brevis. |
| E—Epithelial layer. | |

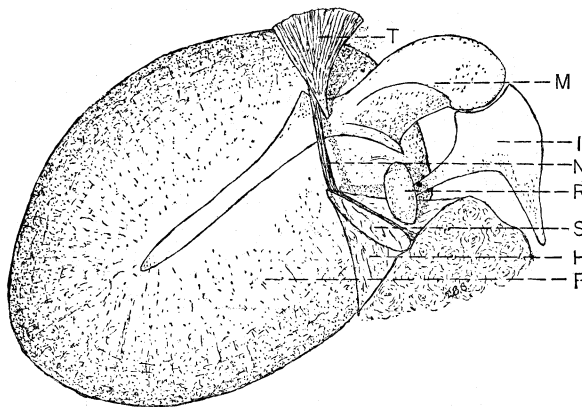


Fig. 10.—Diagram showing the relations of the chorda tympani and its support in the right tympanum of the cat.

- | | |
|-------------------|------------------------------|
| T—Tensor tympani. | R—Stapes. |
| M—Malleus. | S—Support of chorda tympani. |
| I—Incus. | H—Infolding membrane. |
| N—Chorda tympani. | P—Membrana tympani. |

After much careful study of specimens and literature I failed to find a suggestion of the presence of such a support in man. Neither have I in all the literature found mention of it in the cat or any other animal. On dissection, however, I find a similar support of the chorda tympani nerve is present in the lynx and leopard and think it may be a characteristic of the felidæ. It was still present in the dried skull of the leopard and also of the cat. I examined the dried skulls of a few other members of the group and did not find it; but I also failed to find it in one dried skull of the leopard, in two of the lynx, and in a number of the cat. It may be that the animals examined were not old enough for the cartilage to have become calcified, or that calcified cartilage was removed in cleaning the skulls. Heads with the soft parts still in place must be dissected in order to be sure that the support is not present.

I found a support similar to that found in the cat in a dried skull of the hyena.

On dissecting the ears of an orang, baboon, dog, sheep, cheiromys, and loris I found that the support of the nerve was absent in all except possibly the sheep.

In the sheep's tympanum is a small cartilaginous process in a position corresponding to that occupied by the support of the chorda tympani of the cat. It is infolded in the lining membrane, but I am in doubt whether or not it acts as a support to the chorda tympani. The nerve does not come in contact with the cartilage, but it may be slightly supported by the fold of membrane which passes over the top of the cartilage.

It would be interesting to know the object of this raising of the chorda tympani. Perhaps it is to prevent irritation of the nerve by the vibrations of the membrana tympani. Perhaps—and this hypothesis seems to me the more probable—it is to prevent an interference with the vibrations of the membrana tympani.

The Eustachian Tube.

The Eustachian tube extends from the pharynx dorso-latero-caudad to the tympanum. It opens into the tympanum on the cephalic side just dorsad of a projecting shelf of bone. It is about a centimeter and a half in length and opens into the pharynx through a horizontal slit, which is farther cephalad than the corresponding opening in the pharynx of man.

The frame-work of the tube is formed almost entirely of cartilage and fibrous tissue, being bony only where it penetrates the wall of

the tympanum. The frame-work of man's Eustachian tube is osseous for about one-third of its length from the tympanum. The cartilage of the cat's tube consists of a long strip curled upon itself in the form of a trough, a transection being crescent-shaped, and extends the whole length of the tube. It does not extend along two sides of the tube, as in man, but only curls around what is known as the safety tube. It loses its trough-shape near the ends, flattening out somewhat. Glands are found opening into the tube along its whole length, but they are most numerous near the pharynx. The lining membrane of the Eustachian tube, unlike that of the tympanum, is

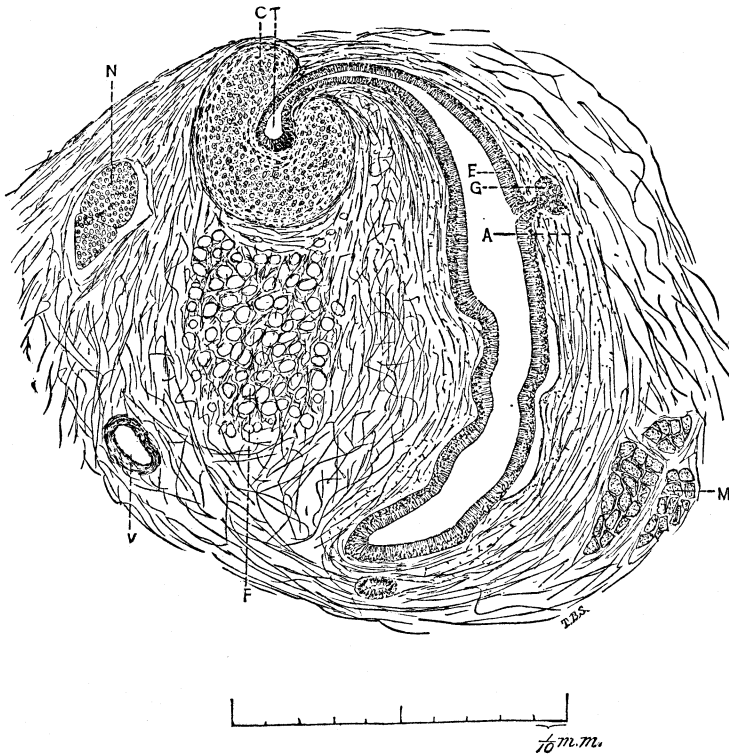


Fig. 11.—Transection of the cat's Eustachian tube.

- | | |
|----------------------|------------------|
| T—Safety tube. | N—Nerve. |
| C—Cartilage. | V—Blood-vessel. |
| E—Epithelium. | F—Fat-cells.. |
| G—Gland. | M—Muscle fibers. |
| A—Connective tissue. | |

covered with three layers of epithelial cells. The ectal layer is ciliated throughout and is made up of columnar cells. The ental layers of cells are smaller and more irregular than the ectal layer (Figs. 11 and 12).

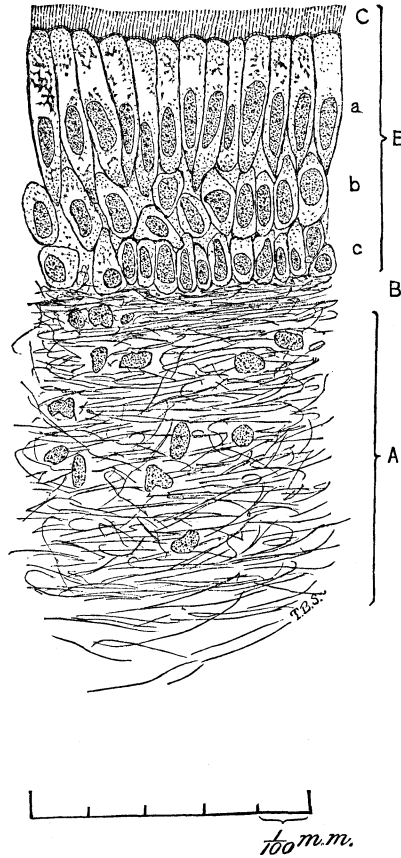


Fig. 12.—Lining membrane of the Eustachian tube of the cat.

- C—Cilia.
- E—Epithelium; *a*, *b*, and *c*—ectal, middle, and ental layers of epithelial cells.
- B—Basement membrane.
- A—Connective tissue.

Summary.

The pinna of the cat is pointed, while that of man is folded over at the helix. The helix and antihelix are not present in the cat's pinna. There are, however, ridges and grooves not found in man's.

The external auditory meatus of the cat has a frame-work which is cartilaginous for nearly its whole length. The frame-work of man's external meatus is almost entirely osseous.

The cat's membrana tympani is thinner than man's.

The cat's tympanum has two chambers, while man's has but one.

The ossicles of the cat's ear are more slender than the corresponding human ossicles.

The tensor tympani of the cat is nearly spherical, while that of man is long and slender.

The chorda tympani of the cat is raised clear of the membrana tympani by means of a small support. This support has not hitherto been described nor even mentioned.

The chorda tympani support is also present in lynx, leopard, and hyena. What is probably the homologue of this support is found in the sheep.

The frame-work of the cat's Eustachian tube has cartilage for nearly its whole length; that of man's tube is bony for nearly one-third of its length from the tympanum. The cartilage does not extend so far around the tube in the cat as in man.

The minute structure of all parts of the external and middle ear is very similar in man and the cat.

Methods.

DISSECTING.

Most of the dissections were made from the meson laterad. The head is first medisected, and then the internal ear is nipped away. The bone of the internal ear is brittle and hard, and since the stapes is closely attached to it by ligamentous fibers at the fenestra ovalis, much care is needed lest the stapes be pulled away with a piece of the bone. This is especially true of the cat, in which the stapes is very slight. By this mode of dissection the relations of the tympanum, membrana tympani, and Eustachian tube can be clearly shown. The relations of the ossicles are also easily seen since these bones are shown *in situ*. The chorda tympani and its support can likewise be shown to advantage. The support can also be shown by breaking

into the bulla and through the bony septum from the ventral side, the internal ear being left in position.

DRAWING.

The drawings of the microscopic sections were all made by means of the Abbé camera lucida. They were made with a pencil, and then transferred in ink.

HARDENING, IMBEDDING, ETC.

Picric alcohol gave the best results as a hardening agent. Flemming's chrom-acetic acid is not good when cilia are to be shown.

The tissues were imbedded in paraffin when either of the above re-agents was used.

The membrana tympani was hardened *in situ* in a .001 per cent. solution of palladium chloride. The manubrium and tympanic ring were decalcified by means of a .1 per cent. solution of hydrochloric acid. The membrana tympani in this case was imbedded in collodion. The epithelial layer did not show clearly by this method, but the failure may have been due to my inexperience in the use of the re-agents and imbedding material.

Of the stains used hæmatoxylin and fluoresceine gave the best results. Ammonia carmine and alum carmine, with or without fluoresceine, both failed to bring out the parts with distinctness.

Xylol balsam and chloroform balsam were used indifferently as mounting media.

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